Effect of biofertilizers and inorganic fertilizers on soil fertility and oil yield of patchouli (*Pogostemon cablin* Benth) in Alfisols

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ABSTRACT

A study was conducted on the effect of biofertilizers and inorganic fertilizers on soil fertility and oil yield of patchouli in Alfisols during 2021-2022. Maximum foliage yield was obtained in treatment of 100 per cent GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant (2.98 tonnes/ha) and 100 per cent GRDF + *Azotobacter* 10 g/plant (2.96 tonnes/ha). Maximum oil yield was obtained in the former treatment (76.66 kg/ha). The soil pH increased to 5.36 to 5.73 from the initial value of 5.16; EC increased to 0.21 to 0.51 dS/m from the initial 0.17 dS/m and OC was enhanced to 2.21 to 2.73 per cent in the treatments from the initial content of 1.51 per cent. The available soil N got enhanced only in the treatment 100 per cent GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant (318.62 kg/ha) from the initial content of 288.51 kg/ha. Available K_2O was significantly highest in the same treatment (274.67 kg/ha) from the initial content of 202.94 kg/ha. Integrated balanced use of fertilizers can improve soil fertility and yield of patchouli crop in Alfisols.

Keywords: Patchouli; yield; biofertilizers; inorganic fertilizers; soil fertility

INTRODUCTION

Patchouli (*Pogostemon cablin* Benth) is one of the important aromatic crops belonging to the family Lamiaceae and is native to Philippines. Its plants are primarily used for their medicinal or aromatic properties in the pharmacy of perfumery and are defined as medicinal and aromatic plants in European Union (Overwalle 2006). Since the demand for patchouli oil is increasing in domestic and international markets, there is huge scope to increase its production by increasing its area. Patchouli oil is a key constituent in exotic perfumes to which it gives a rich, spicy fragrance. Patchouli essential oil is mainly obtained by steam distillation of the shade-dried leaves. It is widely appreciated for its characteristic pleasant and long lasting woody, earthy, camphoraceous odour (Ramya et al 2013). It can also be used as a perfume in its own right. It has also good fixative properties, especially in soap perfumes (Farooqui and Sreeramu 2001). It is cultivated mainly for its essential oil. Shade-dried leaves of patchouli on steam distillation yield essential oil containing about 97 per cent of compounds that do not influence aroma; out of these 40 to 45 per cent belong to the sesquiterpene group and the balance seem to consist of patchouli alcohol (Koul and Nigam 1966).

Patchouli oil is one of the most important essential oils of the perfumery industry as the oil blends well with other essential oils like vetiver, sandalwood, geranium, lavender, clove oil etc. Hence, it is regarded as the best fixative for heavy perfumes imparting strength, character alluring notes and lasting qualities.

To ensure maximum productivity in any crop, proper nutrient supply is an important factor. Among the various nutrients, nitrogen, phosphorus and potassium are the three important nutrients and their application plays a very important role in altering various growth, yield and quality attributes of the plants. However, modern and intensive agriculture calls for a high dependence on fertilizers and chemicals which are not only costly but also cause environmental pollution. Thus by considering the recent concepts of eco-friendly technology, the application of biofertilizers in combination with inorganic fertilizers substitutes the

above need in many crops. However, information on the use of different levels of fertilizers under various planting geometries for enhancing the biofertilizers and inorganic fertilizers use efficiency is very little. There is scarcity of information on the optimization of fertilizer requirement of patchouli planted under different planting geometry. Therefore, a field experiment was conducted to study the effect of biofertilizers and inorganic fertilizers on soil fertility and oil yield of patchouli (*Pogostemon cablin* Benth) in Alfisols.

MATERIAL and METHODS

The current study was conducted in 2021-2022 in the Department of Forest Products and Utilization, College of Forestry, Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra. The initial status of the soil of the experimental field comprised pH 5.16, soil EC 0.17 dS/m, soil organic carbon 1.51 per cent, nitrogen 288.51 kg/ha, phosphorus 7.8 kg/ha and potassium 202.94 kg/ha. Ten treatment combinations were used and framed under randomized block design for the experiment which were replicated thrice.

The treatments were T_1 (Control), T_2 [100% GRDF (gross recommended dose of fertilizers NPK 200:50:50 kg/ha)], T_3(125% GRDF), T_4 [2 KAB (Konkan Annapurna briquettes/plant) (NPK 68:28:12 kg/ha)], T_5 [4 KAB/per plant (136: 56:24 kg NPK/ha)], T_6 [6 KAB/per plant (204:84:36 kg NPK/ha)], T_7 (100% GRDF + PSB 10 g/plant), T_8 (100% GRDF+ VAM 20 g/plant), T_9 (100% GRDF + *Azotobacter* 10 g/plant) and T_{10} (100% GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant). Single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) were used to apply the recommended amount of phosphorus and potash respectively. According to the treatments, urea was used to apply nitrogen. Doses of the mixture of fertilizers were applied at a depth of 2.5 cm below the soil surface. At the time of planting, full dose of phosphorus and potassium was applied. Two equal split applications of nitrogen were made; half dose administered as basal application and second dose at 120 days after planting.

On 1 August 2021, 27,777 patchouli cv Kelker plants per hectare were planted in plots at a spacing of 60 cm x 60 cm. During the period from 1 August 2021 to 31 March 2022, two harvestings were done. The plants were cut 20 cm above the ground. All the plant samples were gathered. Dry herbage yield was calculated and expressed in tonnes per hectare on dry weight basis after the fresh herbage was shade-dried. The oil content of air-dried herbage was calculated utilizing Clevenger's apparatus (Clevenger 1928).

The percentage of oil content was multiplied with the air-dried herbage and the oil yield per hectare was calculated. In situ leaf litter was incorporated in decomposition in soil and laboratory analysis. A representative portion of each soil sample was collected from 0-30 cm depth of initial and litter contaminated soil site which was air-dried, powdered and passed through <2 mm sieve for determination of chemical properties of soil. Soil pH, EC, OC and NPK were determined by standard procedure of Jackson (1973) and available P was determined as per Bray and Kurtz (1945). The experimental data were subjected to analysis of variances (ANOVA) and treatment means were compared and significant differences were tested at P = 0.05 using randomized block design (RBD) as given by Fisher and Yates (1963).

RESULTS and DISCUSSION

Effect of biofertilizers and inorganic fertilizers on yield parameters of patchouli

The data on the effect of biofertilizers and inorganic fertilizers on yield parameters of patchouli are given in Table 1.

Dry foliage yield: Maximum cumulative foliage yield of patchouli from the two harvests was obtained in treatment T_{10} (100% GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant) (2.98 tonnes/ha) and T_9 (100% GRDF + *Azotobacter* 10 g/plant) (2.96 tonnes/ha), which were at par with each other, the latter being at par with T_8 (100% GRDF + VAM 20 g/plant) (2.85 tonnes/ha) and the lowest in T_1 (Control) (2.13 tonnes/ha).

Oil yield: The cumulative oil yield of patchouli differed significantly among the various treatments. Maximum oil yield was obtained in treatment T_{10} (76.66 kg/ha) which was significantly superior to rest of the treatments, followed by T_6 [6 KAB/per plant (204:84:36 kg NPK/ha)] (67.20 kg/ha) and T_9 (64.95 kg/ha), the two being at par. The lowest yield was registered in control T_1 (25.22 kg/ha) and T_2 [100% GRDF (gross recommended dose of fertilizers NPK 200:50:50 kg/ha)] (29.89 kg/ha), which were at par.

Table 1. Effect of biofertilizers and inorganic fertilizers on yield parameters of patchouli

Treatment	Cumulative dry foliage yield (tonnes/ha)	Cumulative oil yield (kg/ha)
T_1	2.13	25.22
T_2	2.41	29.89
T_3	2.62	39.06
T_4	2.53	48.16
T_5	2.62	56.94
T_6	2.70	67.20
T_7	2.78	37.30
T_8	2.85	57.55
T_9	2.96	64.95
T_{10}	2.98	76.66
Mean	2.66	50.29
SEm±	0.04	2.90
$CD_{0.05}$	0.11	9.27

T_1: Control, T_2: 100% GRDF (gross recommended dose of fertilizers NPK 200:50:50 kg/ha), T_3: 125% GRDF, T_4: 2 KAB (Konkan Annapurna briquettes/plant) (NPK 68:28:12 kg/ha), T_5: 4 KAB/per plant (136: 56:24 kg NPK/ha), T_6: 6 KAB/per plant (204:84:36 kg NPK/ha), T_7: 100% GRDF + PSB 10 g/plant, T_8: 100% GRDF+ VAM 20 g/plant, T_9: 100% GRDF + *Azotobacter* 10 g/plant, T_{10}: 100% GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant

Table 2. Effect of biofertilizers and inorganic fertilizers on soil fertility

Treatment	pH	EC (dS/m)	OC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
T_1	5.53	0.21	1.60	263.42	8.73	218.62
T_2	5.39	0.51	2.21	275.97	8.91	225.79
T_3	5.16	0.34	2.28	280.15	10.35	228.03
T_4	5.54	0.20	2.36	296.87	10.04	236.99
T_5	5.38	0.40	1.96	305.24	11.05	241.47
T_6	5.36	0.41	2.56	309.42	9.97	244.16
T_7	5.62	0.41	2.48	250.88	8.06	194.88
T_8	5.73	0.24	2.48	305.24	10.02	153.66
T_9	5.54	0.23	2.70	311.51	10.62	239.14
T_{10}	5.34	0.25	2.73	318.62	11.10	274.67
Mean	5.46	0.32	2.34	291.73	9.89	225.74
SEm±	0.06	0.01	0.21	9.73	0.22	8.61
$CD_{0.05}$	0.18	0.03	0.62	28.9	0.66	25.58
Initial status	5.16	0.17	1.51	288.51	7.8	202.94

T_1: Control, T_2: 100% GRDF (gross recommended dose of fertilizers NPK 200:50:50 kg/ha), T_3: 125% GRDF, T_4: 2 KAB (Konkan Annapurna briquettes/plant) (NPK 68:28:12 kg/ha), T_5: 4 KAB/per plant (136: 56:24 kg NPK/ha), T_6: 6 KAB/per plant (204:84:36 kg NPK/ha), T_7: 100% GRDF + PSB 10 g/plant, T_8: 100% GRDF + VAM 20 g/plant, T_9: 100% GRDF + *Azotobacter* 10 g/plant, T_{10}: 100% GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant

Effect of biofertilizers and inorganic fertilizers on soil fertility

Data on the effect of different treatments on the soil fertility after the harvest of patchouli are presented in Table 2.

The soil pH increased to 5.36 to 5.73 from the initial value of 5.16. Highest increase in pH was recorded in T_8 (5.73) and T_7 (100% GRDF + PSB 10 g/plant) (5.62), which were at par. However, no increase was recorded in T_3 (125% GRDF) (5.16) and T_{10} (5.34), which were at par with the initial value. EC increased to 0.21 to 0.51 dS/m in different treatments from the initial 0.17 dS/m except T_4 [2 KAB (Konkan Annapurna briquettes/plant) (NPK 68:28:12 kg/ha)] (0.20), which was at par with the initial value. OC also got enhanced to 2.21 to 2.73 per cent in the treatments except T_1 (1.60%) and T_5 [4 KAB/per plant (136: 56:24

kg NPK/ha)] (1.96%), the two being at par with the initial content of 1.51 per cent. The available soil N got enhanced only in T_{10} (318.62 kg/ha) from the initial content of 288.51 kg/ha. However, N decreased to 250.88 kg/ha in T_7 from the initial value of 288.51 kg/ha. The available soil P_2O_5 enhancement was seen in T_5 (11.05 kg/ha), T_9 (10.62 kg/ha) and T_{10} (11.10 kg/ha) from the initial content of 7.8 kg/ha. In case of available K_2O, significantly highest enhanced content was recorded in T_{10} (274.67 kg/ha). There was no increase in K_2O content in T_1 (218.62 kg/ha), T_2 (225.79 kg/ha), T_3 (228.03 kg/ha), T_7 (194.88 kg/ha) and T_{10} (225.74 kg/ha), which were at par with the initial content of 202.94 kg/ha. However, there was decrease due to the application of T_8 (153.66 kg/ha).

Manjunatha (2000) reported that 75 per cent NP + 100 K + *Azotobacter* + *Azospirillum* + VAM recorded higher plant height (80.14 cm), number of leaves per plant (357.75), number of branches per plant (22.04), plant spread (76.12 cm), leaf area (4,075.66 cm^2), yield of fresh herbage (10.733 tonnes/ha against 7.277 tonnes/ha in control) and essential oil yield (71.74 l/ha as compared 47.5 l/ha in control) followed by 50 per cent NP + 100 K + *Azotobacter* + PSB + VAM and 50 per cent P + NK + PSB + VAM in case of patchouli cv Johore.

Saha et al (2014) recorded significantly maximum plant height (118.03 cm) in patchouli with the application of 120 kg N/ha in square planting (50 cm × 50 cm) system than all other N levels and spacing except application of 80 kg N/ha in square planting (50 cm × 50 cm). Nitrogen levels significantly improved plant height on all the levels of spacing and there was no significant relationship in plant height and the levels of nitrogen application. They stated that the increase in plant height with application of nitrogen might be due to the effect of nitrogen in promoting the vegetative growth by the enhanced cell division and the greater synthesis of chlorophyll, protein and amino acids. The application of 200 kg N/ha and 41.5 kg K/ha produced significant higher patchouli herbage and oil yield compared with control as observed by Singh and Rao (2009).

Singh et al (2002), while working on patchouli grown on Alfisols, found that irrigation at 1.0 IW:CPE ratio (irrigation water:cumulative pan evaporation), 5 tonnes/ha distilled waste material of palmarosa or 200 kg N/ha produced maximum herbage and oil yields. Organic mulch reduced weed biomass significantly. The highest oil content was recorded with irrigation at 0.8 IW:CPE ratio, no mulch and 100 kg N/ha.

Sumathi et al (2012) reported that nitrogen and VAM had significant effect on yield and yield attributing characters of pachouli. Highest herbage yield (13.60 tonnes/ha) and dry weight of herbage (4.07 tonnes/ha) were recorded with 150 kg N/ha and 5 kg VAM/ha. Essential oil content did not vary significantly among the treatments. Essential oil yield in herbage was highest at 150 kg nitrogen and 50 kg VAM/ha (110.42 kg/ha).

Singh (2011) observed that in patchouli, the application of vermicompost (5 tonnes/ha) + 50 per cent NPK (100:25:25 kg/ha) produced significantly higher herbage and oil yield (13.98 tonnes/ha and 83.4 kg/ha respectively) which was on par with recommended dose of NPK (200:50:50 kg/ha). Application of vermicompost (5 tonnes/ha) + 50 per cent NPK (100:25:25 kg/ha) increased the nitrogen, phosphorus and potassium uptake which was at par with recommended dose of NPK (200:50:50 kg/ha). However, oil content was not influenced by organic and inorganic fertilizers.

Kikon et al (2012) reported that application of vermicompost 5 tonnes/ha alone produced maximum biomass of leaves (11.24 tonnes/ha) followed by pig manure 10 tonnes/ha (10.82 tonnes/ha) and FYM 20 tonnes/ha (9.54 tonnes/ha). Among the various levels of nitrogen, maximum biomass yield of leaves was observed with vermicompost 5 tonnes/ha (11.63 tonnes/ha) with the highest yield (19.97 tonnes/ha) registered through the combination of vermicompost 5 tonnes and inorganic fertilizers 100 kg/ha which in turn maintained higher fungal and bacterial populations for better nutrient acquisition through improvement in the concentration of soil available nutrients.

CONCLUSION

Among the different treatments used, maximum improvement in soil fertility and higher yield of patchouli was obtained with the application of 100 per cent GRDF + PSB 10 g/plant + VAM 20 g/plant + *Azotobacter* 10 g/plant than other treatments. The balanced integrated use of biofertilizers and inorganic fertilizers can improve overall soil fertility and productivity of patchouli in Alfisols of Konkan region of Maharashtra.

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